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Rare Earth Elements: Deep Sea Mining and the Law of the Sea

By Ian Coles [*]

This article presents key legal issues associated with mining in international waters and illustrates the lengths to which corporations and national governments will go to secure their rare earth elements supply chains.

INTRODUCTION

There are 17 rare earth elements ("REEs") including the lanthanides, which occupy the elements from near the bottom of the Periodic Table (atomic numbers 57 to 71), along with the metals scandium and yttrium, which generally occur in the same ore deposits and exhibit similar chemical properties. The lanthanides are commonly divided into: lower atomic weight elements, lanthanum through to europium, referred to as the light rare earth elements ("LREE") and the heavy rare earth elements ("HREE")—gadolinium through to lutetium and yttrium.

The most commercially important REE deposits are associated with magmatic processes and are found in, or related to, alkaline igneous rocks, and carbonatite.

Inaptly named, the REEs' geochemical properties meant that they were not often found concentrated in economically exploitable ore deposits and were thought to be "rare" even though we now know better.

Initially—and for the subsequent 150 years—interest in REEs was almost purely academic. The new elements seemed to have few commercial or industrial applications; indeed extracting them from their ores was too expensive to be viable on an industrial scale. Since the mid-20th century, however, the unique chemical properties of the REEs have led to their use in a wide range of technological applications—and, inevitably, a strong surge in their economic value.

USES OF REEs

We are now reliant on REEs. Many of the electronic devices and technological applications that have come to define the early 21st century are products of the unique chemical properties of REEs. Hybrid vehicles, rechargeable batteries, wind turbines, mobile phones, flat-screen display panels, fluorescent light bulbs, laptop computers, disk drives, lasers, catalytic converters—all are dependent on REE components.

At present, the highest-value commercial application of REEs is their use in the

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manufacture of powerful permanent magnets (praseodymium and neodymium are the principal REEs used in the process, plus small amounts of dysprosium and terbium). These magnets can be used in electric motors to produce greater power and torque, which means that motors and therefore engines can be considerably smaller and lighter in weight. With the depletion of oil and gas reserves, hybrid engines take on a greater share of the energy burden, and our reliance on REEs will increase. A plethora of political commitments have been made, which in some part require the deployment of technology including REEs. REE magnets also allow the miniaturization of hard disk drives like those in mobile devices.

Most energy-efficient lighting and display panels require REEs—chiefly europium, terbium, and yttrium—as phosphor compounds. This is an extremely strong growth sector; manufacturers of LED screens and the like constitute the second-largest commercial REE market.

There are numerous other applications. The nickel-metal hydride ("NiMH") rechargeable batteries used in hybrid cars and countless other electronic products employ a mixed REE alloy (mostly lanthanum). Catalytic converters use cerium as part of the catalyst for converting NOx to harmless Nitrogen, Oxygen and toxic CO to CO2. REEs—again, usually lanthanum—are also present in fluid-cracking catalysts, used increasingly in the petrochemical industry to increase the efficiency of the refining process.

Rare Earths

GLASSES & POLISHING
Ce, La, Pr, Nd, Gd, Er, Ho
Polishing Compounds
Decolorizers/Colorizers
UV Resistant Glass
X-Ray Imaging

CATALYSTS
La, Ce (Pr, Nd)
Petroleum Refining
Catalytic Converter
Diesel Additives
Chemical Processing
Industrial Pollution
Scrubber

METALLURGICAL ALLOYS
La, Ce, Pr, Nd, Y
NimH Batteries
Fuel Cells
Steel
Lighter Flints
Super Alloys

Aluminium /Magnesium

MAGNETS
Nd, Pr (Tb, Dy)
Motors
Disc Drives
MRI
Power Generation
Micro Generation
Microphones & Speakers
Magnetic Refrigeration

CERAMICS
La, Ce, Pr, Nd, Y
Eu, Gd, Lu, Dy
Capacitors
Sensors
Colorants
Scintillators
Refractories

PHOSPHORS
Eu, Y, Tb, Nd, Er, Gd (Ce, Pr)
Display Phosphors CRT, LPD, LCD
Fluorescent Lighting
Medical Imaging
Lasers
Fiber Optics

OTHER
Nuclear (Eu, Gd, Ce, Y, Sm, Er)
Defense (Nd, Pr, Dy, Tb, Eu, Y, La, Lu, Sc, Sm
Water Treatment
Pigments Ce, Y
Fertilizers

GLOBAL REE RESOURCES

With global demand for products containing REEs likely to increase, the search for new stocks of REE ores has assumed huge economic significance.

Until 1948, most of the world's REEs were extracted in India and Brazil. In the 1950s large deposits of Monazite, then the largest source known, were discovered in South Africa. From the 1960s until the 1980s, California's Mountain Pass REE mine dominated production.

Today, the Indian and South African deposits still maintain a small output, and in

2010 the US Geological Survey found that those deposits contained an estimated 13 million metric tons of REEs. By far the greatest producer is China, which produced more than 90 percent of the global supply of REEs in 2012. This figure is made even more impressive by the fact that China is estimated to hold only 25–35 percent of the world's confirmed reserves, mostly in Inner Mongolia.

China's monopoly is even more pronounced with regard to the eight Heavy Rare Earth Elements (also known as the yttrium Group). All of our sources for these elements are in China. Increasing demand for REEs has recently strained supply. There is therefore a growing concern regarding the potential for future shortages; projections suggest that worldwide demand for REEs could soon exceed supply by around 40,000 tons annually, unless major new sources are developed. These concerns have intensified as China, the predominant supplier, has moved to tighten its regulation of exports and crack down on REE smuggling.

China's ostensible motivations in limiting the global REE supply are to conserve scarce resources and protect the environment. Other reasons, however, have been suggested for China's actions. *The Economist* suggested that, by "slashing" their exports of rare earth elements, China would be able to move Chinese manufacturers up the supply chain, "so they can sell valuable finished goods to the world rather than lowly raw materials."

In September 2011, China stopped production at three of its eight major mines. These mines accounted for almost 40 percent of total Chinese REE production. In August 2012, it announced a further 20 percent reduction in production.

The Chinese restrictions on supply failed in 2012, as prices dropped in response to the opening up of other REE sources and, to a degree, stockpiling of existing reserves. But the search for alternative sources—in Australia, Brazil, Canada, South Africa, Tanzania, Greenland, and the United States—goes on. Mines in many countries were closed in the 1990s when China's Stakhanovism REE output triggered a global fall in prices but, as supply falters and demand continues to increase, re-opening these facilities is becoming economically viable. The once world-leading Mountain Pass mine in California resumed limited operations in August 2012; other significant sites are under development in central Australia and northern Canada. The Canadian deposit alone has the potential to supply about 10 percent of North America's annual $1 billion REE consumption. Vietnam began supplying Japan with Rare Earths in 2010, while a potential mine site in east Africa, the Tanzanian-based Ngualla project, is reported to contain the sixth-largest deposit by tonnage outside of China, and is of very high grade. The development by China of REE projects in Greenland has created another potential hotspot; the Greenland government has so far resisted pressure to restrict further Chinese exploration.

THE ENVIRONMENT

The environmental costs associated with Rare Earth extraction, purification, distribution and disposal can be significant. Bayan-Obo, China's largest REE project, has been operating for more than four decades. According to the Germany-based

Institute for Applied Ecology, the site now has an 11 Km2 waste pond, with toxic sludge that contains elevated concentrations of thorium.

Research by the Washington-based Institute for the Analysis of Global Security suggests that China's undemanding environmental standards have allowed it to produce Rare Earths around two-thirds more cheaply than its international competitors.

The institute's report noted that China "has never actually worked out pollutant discharge standards for the rare earth industry." Many of the environmental problems associated with REE processing arise from the fact that the elements occur in China's ores only in very low concentrations. They therefore have to be separated and purified using hydro-metallurgical techniques and acid baths. The waste liquids sluiced from the process into the tailings pond contain not only toxic chemicals like fluorine but also radioactive elements.

China's remarkable monopoly on the rare earths may, however, soon be fractured. A new plant, based in Malaysia but run by Australia's Lynas Corporation, started reefing REEs in February 2013; although they are not processing at full capacity while REE demand remains depressed, the plant is likely to become the world's largest REE processing facility.

ENVIRONMENTAL COMPLIANCE

Seabed mining remains politically and environmentally challenging. Environmental concerns which organizations such as The Ocean Foundation are concerned about include:

- Physical disturbance and destruction of benthic habitat and seabed fauna. In addition to potential destruction of these organisms, they are in turn eaten by other marine life (which could have an impact on the upwards food chain).
- Subsurface noise affecting marine mammals and fish.
- Modification of the natural wave and current regime through removal or addition of substrate (potential coastal erosion both up and downstream).
- Risks associated with increased infrastructure, e.g., oil spills from vessels.
- At the Solwara 1 site (Papua New Guinea) a particular concern is that stocks of tuna could be contaminated by heavy metals and affect consumers eating such tuna.

In recognition that the full impact of deep seabed mining activities on the deep sea environment and marine ecosystem still remains unknown, the ISA regulations on prospecting and exploration specifically impose obligations on each contractor to monitor, evaluate and report to the ISA the environmental impacts of deep seabed mining.

OCEAN MINING AND THE LAW OF THE SEA

"The hydrosphere is the new frontier in mining." These were the words in 2011 of Mike Woodbourne, then the CEO of the Australian marine mining firm Bonaparte Diamonds. This new frontier certainly offers substantial potential rewards in terms of previously untapped mineral resources—but it also presents significant challenges. No technology has yet been developed to effectively mine deep-sea minerals at a cost comparable to that of land-based mines.

The pioneering firms that sought to target ocean-floor Manganese nodules in the 1970s quickly ran into seemingly insoluble difficulties with regard to costs and efficiency. Ocean-floor mining was simply not economical.

Now, however, the long-developing industry's time might finally have come. Some enterprises—including a number of state-owned operations—have been prospecting since 1984 and are preparing to begin exploitation in earnest.

Reports indicate that deep-sea mining is now attracting significant investment. Game-changing new technologies and heightened demand for mineral resources have transformed the economics of the industry.

Global metal and mineral mining output was valued at $644 billion in 2010, but mining as a whole is still facing challenges; resource extraction continues to move to ever remoter and more inhospitable locations. Deep-sea mining today accounts for almost none of that global metal and mineral supply—but that could change dramatically. Industry projections suggest that by 2020 the deep-sea sector could be providing five percent of total mining output, rising to 10 percent by 2030—a value of some $65 billion in 2010 prices.

But such a level of output would barely scratch the surface of the potential resources present—if tantalizingly out of reach—beneath the sea. The value of total ocean-floor gold deposits, for instance, has been put at $150 trillion at today's prices. A UN official has described the scale of the oceans' mineral deposits as "staggering."

These remain very early days. UK Seabed Resources, a government-backed British subsidiary of Lockheed Martin, has secured a license from the UN to explore a 4,000 meter-deep area of Pacific seabed twice the size of Wales.

Another mining project, financed by Nautilus Minerals off the coast of Papua New Guinea, is already underway, though controversy is not far away: the Papua New Guinea government is challenging the terms of Nautilus' deal, and environmentalists have questioned the adequacy of the Environmental Impact Assessment carried out before mining began. Exploration continues but a date is set for arbitration in August. Investors in Nautilus include Metalloinvest, Anglo American, MB Holding, an Oman-based group.

The search for REEs has so far accounted for only a negligible proportion of deep-sea mining activity. However, recent reports indicate that Japanese scientists have found a large source of REE ores in the Pacific Ocean, east of Tokyo. The deposit, estimated at around 6.8 million tons, is lodged in deep-sea mud 5,700 meters below sea level, around the island of Minami-Torishima; it is the first deposit of its kind to be found in Japan's Exclusive Economic Zone.

Encouragingly, the Japanese deposits may not—by the standards of the industry—be excessively difficult to extract. Although they are deep underwater, the deposits are in highly concentrated nodules that can be extracted using pressurized air. Disturbance to the sea floor would be minimal; toxic acid leaching would not be necessary. What's more, the high concentration of the ore deposits means that the relative cost of extraction would be low enough to make the project economical, according to team leader Professor Yasuhiro Kato of Tokyo University.

It is thought that the levels of the economically important Heavy REEs in the Minami-Torishima deposits are much higher than in Chinese ores; the discovery might therefore provide the leverage Japan needs to break China's monopoly on REE production.

Professor Kato questions the motivations of the current market leader. "[China's] real intention is to force foreign companies to locate plants in China," he argues. "They're saying, 'If you want our Rare Earth metals, you must build your factory here, and we can then steal your technology.'"

Japan's industries account for almost 60 percent of global REE consumption. Based on the known distribution of REEs on land, the Minami-Torishima find could lead to the discovery of further, similar offshore stocks.

BARRIERS TO OCEAN MINING

Frank Sansone, an oceanography professor at the University of Hawaii, has emphasized the gulf that exists between the presence of deposits and the realistic prospect of extraction. "It's not just something that you can glibly say, 'Oh, this is a huge amount of Rare Earth,'" he told *Popular Mechanics*. "It would be difficult to exploit. There's a big difference between saying that the elements exist in large amounts and being able to appropriately, economically and environmentally extract that material."

John Wiltshire, director of the Hawaii Undersea Research Laboratory, told the same journal, "The truth of the matter is, nobody's going to mine in the deep sea—even if somebody massively funds this—for a minimum of a decade. The start-up cost could run from $1 to $2 billion." The academic community clearly has not fallen for the deep-sea hype. The pair have spent their entire careers studying ocean-floor mineral deposits—including rare earth mineral deposits. "I published a paper on this 25 years ago," Wiltshire said. "The first papers that indicated Rare Earth minerals go back 30 or 35 years. People have been talking about mining manganese nodules since the 1960s."

Now, as then, cost and time remain enormous hurdles to any business—or government—planning on reaping a fortune from ocean-floor mining. In conversation with *Popular Mechanics* earlier this year, Wiltshire cited the planned Nautilus mine off the coast of Papua New Guinea as an instance of the extreme challenges facing deep-sea miners. Nautilus hopes to build a $157 million ship to support what could be the world's only deep-sea gold and copper mine; it would have to be 680 feet long, with a deadweight capacity of more than 20,000 tons, and bunks for up to 160 people. The Nautilus project would see three remote-controlled devices—two cutters and a collector—lowered to the sea floor, some three miles down. It is thought that an as-yet-undesigned pump system would be used to lift the ore from the seafloor to the giant ship. "They've already spent about $400 million," Wiltshire said. "The boat will be a couple hundred million. A complete operation for Nautilus will easily be a billion."

Deep-sea deposits typically contain a 0.2 percent concentration of rare earths; deposits on land can have five to 10 percent concentrations. The obvious question regarding deep-sea REEs is not "Are they there?" or "Can we extract them?" but "Is it worth it?" China's monopoly seems likely to endure for at least a little while yet.

MINERAL MATTERS—THE LAW OF THE SEA EXPLAINED

The international legal framework for deep seabed mining stems from Part XI of the 1982 United Nations Convention on the Law of the Sea (the "UNCLOS") and the 1994 Agreement relating to the Implementation of Part XI of the UNCLOS. There are 166 States Parties to the UNCLOS.

A Dual Regime

The UNCLOS confers sovereign rights on coastal States Parties to explore, manage and exploit resources located within their respective continental shelves, which is broadly defined in Article 76 as the seabed and subsoil extending up to 200 nautical miles from the shore. This is known as the "Exclusive Economic Zone." Accordingly, a coastal States Party may develop its own policies to permit and regulate deep seabed mining within its national jurisdiction. That said, Article 235 of the UNCLOS also imposes a general obligation on all States Parties to protect and preserve the marine environment, both within and outside areas of national jurisdiction.

The seabed beyond the limits of national jurisdiction—referred to as "the Area"—and the minerals in the subsoil are declared by the UNCLOS to be "the common heritage of mankind." Accordingly, the exploration and exploitation of resources in the Area must be carried out "for the benefit of mankind as a whole." Based on this premise, an independent body—the International Seabed Authority ("ISA")—was established by the UNCLOS in 1994 to regulate and control seabed mining activities in the Area, with the 166 States Parties to the UNCLOS automatically becoming members of the ISA.

Regulation of Deep Seabed Mining in the Area

In the Area, activities in relation to seabed mining may only be carried out in accordance with the regulations, rules and processes laid down by the ISA (the "Mining Code"). Engaging in prospecting[1] requires a satisfactory undertaking to be given to the ISA that the proposed prospector will comply with the UNCLOS and the Mining Code and will accept verification of compliance by the ISA. Exploration[2] and exploitation may only be carried out under a contract with the ISA, which may

[1] This is defined in the Mining Code as the searching for minerals without any exclusive rights.

[2] This is defined in the Mining Code as the searching for minerals with exclusive rights, the analysis

be awarded to state agencies and private mining enterprises sponsored by a State Party to the UNCLOS. The element of state sponsorship is fundamental to this regime, as it is designed to ensure that a State Party to the UNCLOS is ultimately responsible for the activities of entities which contract with the ISA. To date, the ISA has awarded 19 exploration contracts, each valid for 15 years, with a further three contracts in the pipeline. The rapid increase in activity for the ISA in recent years reflects the renewed interest in deep seabed mining, especially from the private sector.

The complete legal framework on the activities in the Area has yet to be developed by the ISA, as the current regulations are limited to prospecting and exploration. In view of the fact that many of the contracts will expire in 2016, the ISA has published a technical study in February 2013, setting out the issues which should be addressed in a regulatory framework for exploitation, such as the licensing procedure, the fiscal regime and the division of profit and risk. The stated aim is that the regulations for exploitation will be in place by 2016.

National and Regional Efforts

The government of Papua New Guinea awarded a license for the world's first commercial mining operation to Nautilus Minerals, a Canadian firm, in 2012. However, Nautilus' Solwara 1 project is currently on hold as Nautilus is in dispute with the Papua New Guinea government over the terms of government participation in the project.

As the commercial interest in deep seabed mining grows in the territorial waters of the South Pacific region, a legislative and institutional framework will need to be developed by each coastal state at the national level to ensure that the exploitation of seabed minerals within its national jurisdiction is controlled and managed. The recognition of this need has culminated in the Pacific-ACP States Regional Legislative and Regulatory Framework for Deep Sea Minerals Exploration and Exploitation (the "Framework"), which was prepared under the regional project launched in 2011 with funding from the EU and implemented by the Applied Geoscience and Technology Division of the Secretariat of the Pacific Community. The Framework seeks to provide the Pacific Island states with the tools and guidelines for the formulation of a comprehensive national policy, legal framework, and institutional capacity to regulate and monitor deep seabed mining.

The most proactive of the Pacific Island states has been the Cook Islands, which has enacted national legislation—the Seabed Minerals Act 2009. Mark Brown, the Cook Islands' finance minister, told *The Guardian* that the Cook Islands "have the only legislation in the world dedicated to deep water minerals" mining. He believes the minerals on the bottom of the South Pacific could increase gross domestic product a hundredfold and that the seabed surrounding the Cook Islands could transform the nation into one of the richest in the world in terms of per-capita income. Brown also told *The Guardian* that they would expect stakes in mining

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of such minerals and testing of equipment and facilities and the carrying out of studies of the factors that must be taken into account in exploitation.

companies for free in return for the rights to exploit its resources. Tenders may be granted by June 2014.

As for the United Kingdom, a bill was introduced to the House of Commons in June 2013—The Deep Sea Mining Bill 2013-14—which (if passed) will apply to England and Wales and Northern Ireland, to amend the provisions of the Deep Sea Mining (Temporary Provisions) Act 1981 (which was passed prior to the UNCLOS) to make it consonant with the UNCLOS. The provisions apply to the Area (rather than the Exclusive Economic Zone).

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